COKE BREEZE BRIQUETTING

BY

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ARMOUR INSTITUTE OF TECHNOLOGY

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COKE BREEZE BRIQUETTING

A THESIS

PRESENTED BY

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TO THE

PRESIDENT AND FACULTY

OF

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PREFACE

In the selection of this subject the object is that it is work of a progressive nature, open to the further carrying on by students of the Mechanical Engineering Department in the years to come.

The subject has herein been presented in two parts; the first, a survey of the previous work done and important factors; and the second, an application of these to the development of results.

In Part I is given a survey of the general factors involved, together with a review of several of the most commonly employed methods of today.

In Part II is given the description of the tests performed and the conclusions evolved.

The author desires to express his gratitude and indebtedness to his instructor, Pro-

28102

Preface

fessor James Clinton Peebles, the Malcolmson Briquetting Co., and the By Products Coke Corporation whose interest and co-operation made this report possible.

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PART I.

A survey of the general factors involved, together with a review of several of the most commonly employed methods of today.

INTRODUCTION

Coke Breeze is to the coke industry what the culm pile is to the coal mine. Each represents a fuel that at one time had no value although containing sufficient heat units to warrant burning if means could be found to burn. it.

The culm pile has had the good fortune of being utilized in recent years, but the waste of the gasless fuel still is one of the unsolved problems waiting for the hand of progress to make use of it.

The work here inscribed is entirely devoted to briquetting the fuel so that it might be burned in the same manner as lump coal. Coke breeze Briquettes have been manufactured with varying initial success which has always resulted ultimately in failure. The three causes for failure are; first, the wear and tear on the machinery and dies;

secondly, the cost of manufacture; and thirdly, the intense smokiness of the fuel resulting in its poor market value.

It is the ultimate object of this thesis that the results may assist others in the future to master them.

GENERAL SURVEY OF SUBJECT

Coke Breeze is the refuse that is taken from coke ovens when they are drawn. Many attempts have been made to burn it under hand fired conditions with varying degrees of success. One of the difficulties has been to keep firemen because of the arduous labor.

Ordinary coke breeze as a fuel in a common grate and design of furnace is not successful. The breeze packs as a heavy dust upon the grate much in the same manner as fine sand. With the least jar it starts flowing and soon is all deposited in the ash pit. It can be handled easily in its wet condition and will pack and hold together to a limited degree. The moment the water is evaporated off, however, all cohesive properties are lost and it resumes all its former characteristics. In order to blow through this heavy mass, a heavy draft is required. This heavy pressure

breaks through the weakest places and soon the fire bed is full of blow holes.

Coke Breeze consists of small particles of coke broken off when the coke is drawn and crushed. These small particles necessarily broke because they were more loosely attached than the other particles. The most common cause of this weaker cohesion is a small particle of slate. Coke breeze is therefore very heavy in ash.

The ignition of coke breeze is slow. This is due to the structure of the substance. Even the smallest particles are regular honey combs of air cells. These form a wonderful insulator and thus delay the communication of heat. Great surface and small depth are then the chief essentials for its combustion.

These various difficulties would seem to have been over come if the coke breeze were formed in compact lumps. This has seemingly been accomplished by briquetting. Briquettes

have been made by mixing Bituminous coal, together with the coke breeze and pitch. The briquettes form an ideal fire bed. Great surface is exposed. They hold apart due to their shape and allow a fine passage of air through the bed. This reduces the draft required to a minimum.

There is this drawback, however, as before mentioned: In their manufacture they cut and wear the dies to an enormous degree. This is due to the hard slate particles which are extremely sharp. They are embedded in the carbon and form an ideal grinder. A new method of manufacture whereby this difficulty will be obliterated is, therefore, highly desirable and has been summarily dealt with.

The cost of manufacture is also a very serious question. All the apparatus which has been necessary curtails a vast expenditure of capital with its subsequent depreciation. The cost of the coal used in the manufacture

plus the cost of the process and labor has not produced a product capable of bringing a market value high enough to justify the expenditure of the enterprise.

The cause of this lower market value is due; first, to the skeptism of the people. The consumers unquestionably prefer coal or some common fuel to the smoothe compounded briquettes. The briquettes seem to hold properties which may be varied at the manufacturers' will. In this way good results may be obtained from one lot, while the next might be camouflaged, so the average buyer thinks. With coal he absolutely knows what he is getting. Secondly, the briquettes burn with a very smoky flame due to the large amount of volatile matter in the fuel. The soot collects heavily in the flues and passages causing constant cleaning and care.

To do away with this last great hindrance, that keeps the coke briquettes from the market, has been the object of many tests herein carried on.

METHODS IN USE TODAY

- Coke Breeze Used Directly -

Ordinary coke breeze as a fuel in a common grate and design of furnace is not successful. About the year of 1896 a series of experiments in burning this fuel under return tubular boilers were carried on by Chas. N. Nays of the F Coke Company of Mount Pleasant, Pa. At the initial stage of these experiments no special furnaces were used and the same relative distances between the grates and the boiler were maintained as when burning coal.

It was soon found that the fuel required a forced draft to furnish the necessary air supply so the steam jit type was adopted. The coke could be handled in only a quiescent state.

The use of stokers that aggitated the fuel resulted in a mass of clinkers sufficient to shut down the plant after a few hours run,

Methods In Use Today.

The plant then had to be shut down and the fires cleaned. The average Bee Hive oven coke breeze contains from 25% to 35% sand, sulphur, and free ash. All this combines to make up a solid clinker formation. To handle the clinkers produced in burning this fuel a specially designed rocker, cutting, and dumping grate is used. The fire bed is carried about eight inches thick at the front of the furnace. As the grates are dropped three inches for stoking this must be the case.

As the clearance spacing between the bars is the same nothing but fine ashes are dropped into the pit. The shaking movement is so slight that the fire bed is not disturbed to any great extent. This movement also prevents the amalgamation of clinker forming impurities.

The fuel bed is carried and divided into three zones. The first is about five

inches thick at the front to fifteen inches at the back. This residue formation diffuses the air over the grate and prevents the formation of blow holes in the fire that would be caused by an unequal distribution of air pressure.

The second fuel zone is carried about three inches thick, all over the grate surface and is composed of the incandescent particles of carbon in the fuel. The moisture is evaporated in the third zone, which consists of green fuel that is continually sprinkled over the second zone. The moisture is evaporated from the heat below and also from the arch above. The cutoff movement of the grates are operated every two hours, which removes about one inch of the bottom residue at each stroke. In this way the fires are cleaned without the use of fire tools.

Methods In Use Today.

- Coke Breeze Briquetted -

The By Products Coke Corporation carried on a series of important tests which gave valuable data and information on the subject. Mr. Allen, Superintendent of the South Chicago Plant is responsible for all the matter here inscribed. He is a graduate of Ann Arbor and had charge of a great deal of the work.

The By Products Co., used a plunger type of press to start with for briquetting. The mixture used was:

65% Coke Breeze
25% Pocahontas Coal
9% Pitch

They had to cease operating the plant in one month because the dies could not stand the wear that they necessarily were subjected to. The briquettes were also too large to be burned efficiently, and, therefore, were of

little value on the market.

They next put in a new machine which made a small cushioned shape briquette about two inches in diameter. The mixture was also changed to:

53% Pea Coal
38% Coke Breeze
9% Pitch

The mixture gave a strong briquette which was very much in demand on the market. In a couple of months this machine had worn out and new dies had to be put on. The work went on but the machine was in constant repair. The chief troubles: first , the dies wore out quickly, and second, the wheels were only 20" in diameter and the turning effort was so great that an exceedingly large amount of power had to be used.

Although the fuel found a ready market it also brought numerous complaints because of the

dense smoke.

This machine was finally abandoned, and a new machine was designed with larger wheels. The diameter of these wheels were 3' and were made of manganes steel. This machine was very satisfactory outside of necessarily heavy wear.

The mixture was changed to:

38.7%	Hocking Valley Coal
51.4%	Coke Breeze
9.9%	Pitch

This mixture produced a very pretty briquette. This machine was finally and all work stopped. The chief reasons were; first, the fuel smoked; second, it could not be produced at a price to compete with the cheap smoking fuels it had to compete with, and third, the cost for wear and tear on dies was prohibitive.

During the process of manufacture other

Methods In Use Today

points were found out which also were equally important. When the coke was ground wet, the wear on the crusher was enormous. The wet breeze acted as a carborundrum wheel would with very disasterous effects. It will simply grind away the steel like it were cheese. The coke is,therefore,always dried which is most easily done by allowing it to pass through a long revolving steel cylinder. The moisture comes off very easily and quickly. It is very easily crushed when dry.

The mixture of tar and coke was found most easily heated for briquetting by steam jets. As the steam is superheated no moisture can adhere to and spoil the mixture.

PART II.

Investigation of the materials used together with a description of the tests performed and the conclusions evolved.

INVESTIGATION OF MATERIALS USED

In order to accomplish the best results with the least amount of fruitless work a thorough knowledge of the subject and a complete investigation of the materials used is absolutely essential. The characteristics properties and composition of the materials have been studied closely. This has been relatively easy as only two are used. These are respectfully coal tar and coke breeze. Only these two have been used as they afford the most simple combination if properly proportioned and treated.

Coke Breeze.

The coke breeze was obtained from the "By Products Coke Corporations." The material was a pure sample and came directly from the ovens. It was excellent in that it contained no elements other than that to be expected if the product were in demand. There

were three bags sent whose aggregate weight totaled three hundred pounds.

The appearance of the coke breeze was very similar to that of the ordinary cinders used in paving. The substance was still wet not having had evaporated off the water poured upon it to cool it when drawn from the ovens. It consisted of all particles that would pass through a one half inch mesh sieve. There were considerable of the larger particles of the substance in evidence.

A fair sample of the substance was secured by quartering. The three bags of coke breeze were emptied upon the floor and thoroughly mixed by shoveling. It was then divided into four piles. Three were removed and shovelled back into the bags. The fourth quarter was thoroughly mixed, quartered, and three of its parts removed. This operation was repeated until only a pail full

remained. This was ground and again quartared until a small sample was left. With this an analysis of the coke breeze was made.

Moisture.

A watch glass was carefully weighed on a chemical balance. A few grams of the coke breeze was then put in it and the total weighed. It was then inserted in an electric oven for one hour and the temperature kept constant at 212 F. After being heated it was removed and weighed..

Results.

Wt. of Watch Glass - - - - - - - - -	16.6026 G.
Wt. of Watch Glass & Coke - - - -	21.0000 G.
Wt. of Watch Glass & Coke - Moisture	20.6036 G.

Making:

Original Wt. of Coke - - - - -	4.3974 G.
Final Wt. of Coke - - - - -	4.0010 G.
Wt. of Moisture - - - - -	0.3964

Investigation of Materials Used.

% of Moisture eq. $\frac{.3964}{4.3974}$ or 9.04%

Volatile, Fixed Carbon and Ash.

Volatile:

The weight of the crucible was found and the Coke and Crucible in the same manner as before. It was then placed over a bunsen flame. The tip of the flame just touched the crucible. A cover was kept on and the coke heated for seven minutes. It was then removed and reweighed.

RESULTS

Wt. of Crucible & Cover - - - - - 19.5700 G

Wt. of Crucible, Cover & Coke - - 22.0000 G

Wt. of Coke - - - - - - - - - - - 2.4300 G

Wt. of Crucible, Cover & Coke moisture and Volatile free - - - - - - - - - - 21.6389 G

Investigation of Materials Used.

Wt. of Volatile Matter and Moisture - 0.3611

$\frac{0.3611}{2.4300}$ or 14.85%

% of Volatile Matter equal 14.85 - 9.04 or 5.81%

ASH

The crucible was then put over the gas blast burner and the coke remainder of the preceding test was burnt. It was heated and weighed repeatedly until no depreciation in the weight was observable.

RESULTS

Original Wt. of Coke - - - - - -	2.43 G.
Resulting Wt. of Ash - - - - - -	0.4097 G

% Ash equals $\frac{0.4097}{2.43}$ or 16.85%

% of Free Carbon equals

100 - (14.85 + 16.85) eq. 68.3%

Investigation of Materials Used.

SUMMATION OF ANALYSIS.

Moisture	9.04%
Volatile Matter	5.81%
Ash	16.85%
Carbon	68.30%
	100.00%

By means of the bomb calorimeter the B.T.U. of the fuel was found to be 10,608.

Investigation of Materials Used.

COAL TAR

The Coal Tar was of a Medium grade manufactured by the "Yankee Coal Tar Products Co." It was chosen for the work as it represented an average commercial product easily to be found upon the market at any time. Medium Grade in coal tar pitch is that grade that softens at 90 degrees Fahrenheit. It is more plentiful because of the distilling process where it is found easier to remove at this density from the stills.

Analysis of Tar for Coke.

A crucible of the tar was heated over a bunsen flame with the cover on. Heat was applied until no more volatile matter was driven off. The crucible and contents were weighed and the percentage of coke residue noted. The coke was collected in the bottom of the crucible in a solid mass which was only broken by the application of considerable pressure.

Investigation of Materials Used.

RESULTS

First Trials:

Wt. of Crucible and Cover - - 11.4320 G.

Wt. of Crucible, Cover and Tar - 21.3420 G.

Wt. of Tar - - - - - - - - - - 9.9100 G.

Wt. of Crucible, Cover and Tar after the heating process - - - - - - - 14.7610 G.

Wt. of Coke - - - - - - - - - - 3.3290 G.

% Coke Eq. $\frac{3.3290}{9.9100}$ or 35.57%

Second Trial:

Wt. of Crucible and Cover - - - - 11.6420 G.

Wt. of Crucible, Cover and Tar - 22.7530 G.

Wt. of Crucible, Cover and Tar after the heating process - - - - - - - - - 15.1640 G.

Investigation of Materials Used.

Wt. of Tar - - - - - - - - - - - - 11.1110 G.

Wt. of Coke - - - - - - - - - - 22.7530 G.

$$\text{Coke \%} \quad \frac{3.5220}{11.1110} \quad \text{or} \quad 31.70\%$$

Average of the two Equals

$$\frac{31.70\% + 33.57\%}{2} \quad \text{or } 32.64\%$$

The results here found are of considerable importance as a guide in later operations. From this fundimental test can be derived these rules.

When coke breeze is mixed with coal tar and heated, approximately two-thirds of the tar can be recovered. The remainder is deposited in and between the pores and particles. It there acts as a cement and unites the granuales in one solid mass. The actual binder used can then be considered as only.

Investigation of Materials Used.

One third of that used in the mixture. This enables a large amount of binder to be used, in the initial process with relative economy.

Test for Brittleness.

The tar was first cooled by surrounding it by ice. The mortar and pistol were also similarly treated. They were thus cooled down to a very low temperature. The tar was then worked in the mortar and demolished quite easily to a fine powder. It was then allowed to warm up gradually from the heat of the room. A thermometer was kept in the mixture so that a close record of the temperature was kept. At equal intervals of temperature the substance was ground. As it warmed up all signs of brittleness gradually disappeared. The point at which all of the brittle-

ness disappeared and all of the intermediate characteristics were noted. The following characteristics were noted:

Temp.	Characteristics.
50	They ground very easily.
53	They ground very easily.
57	They ground very easily.
60	They showed a slight tendency to bind.
62	The critical point was reached as the dust particles collected and packed solid in the bottom of the mortar.
64	The particles mashed and no signs of brittleness were displayed whatever.

The pitch was now tested for brittleness,

this time from the opposite phase.

The tar was immerced in water whose temperature was 80 degrees Fahrenheit. A thermometer was suspended in the liquid. Ice was then put in the water in small quantities and the temperature was then subsequently lowered quite gradually. At every few degrees drop the pitch was removed, placed in the mortar and ground.

The following characteristics were observed;

Temp.	Characteristics.
80 - - - - -	Soft. If allowed to stand one piece on another, the pieces would soon seemingly flow together.
75 - - - - -	Soft, but the pieces did not display the tendency to flow together.

Investigation of Materials Used.

Temp.	Characteristics.
70	It became harder but could be easily pressed out of shape.
68	It assumes more or less of a solids characteristics.
65	It requires the application of a great deal of pressure to mash but will not break up into particles.
62	It starts to crack under pressure but will not crumble.
60	It cracks and does not mash together.
58	It breaks into fine dust quite readily.

Investigation of Materials Used.

From these results the following notable and important points were evolved:

If a dry mixture is to be made for briquetting with some other ingredient the temperature must never become lower than 60 degrees Fahrenheit during the entire process. If the temperature does fall below this point the whole will become a conglamorated mass and would cause no end of trouble. The tar also cannot be ground unless it is lowered below this point as it would clog in the machinery and might stop its operation entirely.

Test For Sticking Point.

Two pieces of the pitch were immerced in water whose temperature was 60 degrees. A bunsen Flame was then applied beneath the containing vessel. The flame was only about one inch long so that the temperature

would rise quite gradually. A thermometer was suspended in the water so that the temperature was always obtainable. The two pieces of pitches were now placed together at intervals and the characteristics noted.

Temp.	Characteristics.
60 to 80	It gradually became softer during this range of temperature.
92	It started to show a tendency to adhere but broke instantly apart when pulling.
95	It became exceedingly soft to the touch. The pieces would stick but broke apart when tension was placed upon them.
98	They adhered to each other permanently only upon the appli-

	cation of continuous heavy pressure.
105	They united with little effort at this temperature.

Melting Point.

The tar was placed in a pan and heated slowly by the application of a bunsen flame. A thermometer was suspended in the liquid.

Temp.	Characteristics.
115	The pitch readily flowed becoming a thick heavy liquid.
225	It became quite fluid and is approximately in its most liquified state.
250	It boils in much the same manner as water.

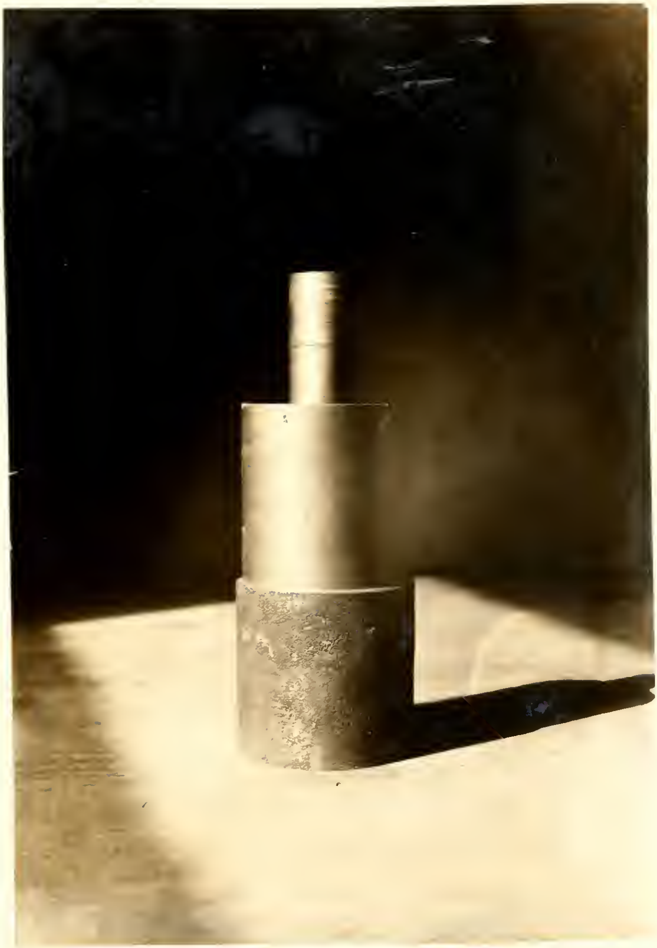
Investigation of Materials Used.

From these last results the following important points were noted.

I. As the tar only starts to stick or adhere at 105 degrees no briquettes should be made with the mixture below this temperature.

II. During the process of hot mixing the temperature should range between 225 and 250 degrees in order to have the most fluid liquid to work with.

III. At this temperature of manufacture all moisture originally in the fuel would be evaporated. If the coke breeze was of sufficient fineness no preliminary drying would be necessary.



Cast Iron Mould and Steel Plunger

Used in Briquetting.

INVESTIGATION FOR THE CORRECT COMPRESSING LOAD

In order to design the machinery to be used and the most economical briquette to be made, the effect of loading must be known. This is very important also for the quality of the briquettes. As the load is applied there is a point reached where any additional force does not produce any appreciable further compression. This point is the object of the following test.

In order to apply a known load upon an element of area a special apparatus was made. This consisted of a cast iron cylinder as is shown in the sketch with a whole through the center exactly one square inch in cross-section. A steel pistion was turned to act as a plunger in this opening.

Correct Compressing Load

A 10% mixture of coke breeze and pitch was made. The coke breeze was ground in an electric grinder and passed through a ten inch sieve. It was then weighed out, put in a pan, and heated to 250 degrees. It was constantly stirred so that the temperature was uniform throughout. The proper proportion of pitch was now added. It was in its liquid condition. Upon stirring the two worked into a plastic mixture quite easily. The mould and plunger were then heated to the same temperature.

Two and one-half ounces of the hot mixture was then put in the mould. It was then put in an Olson's Texting Machine. A load of 100 pounds was first put on. A reading was then taken of the length by means of inside calipers. A new load was then put on and a new reading taken. This operation was repeated for regular increment of loading.

Briquetting Mould In Olson's

Testing Machine.

Correct Compressing Load.

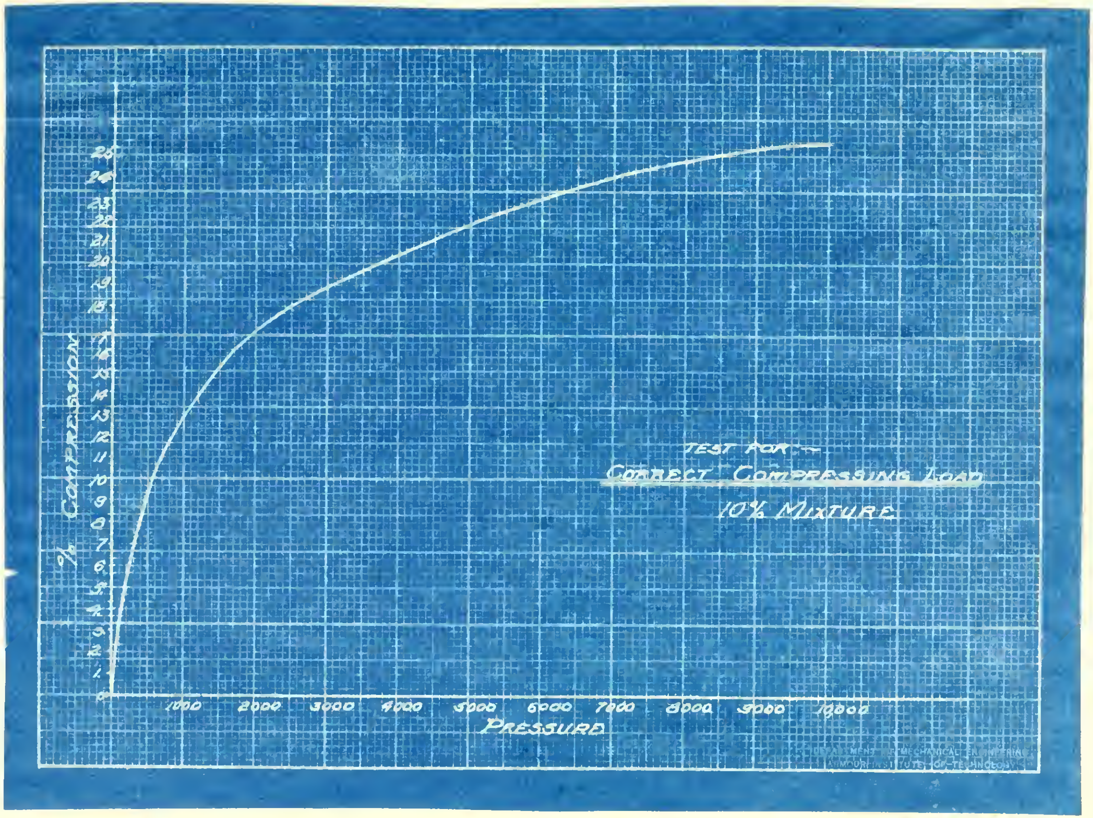
TEST FOR % COMPRESSION 10% MIXTURE.

Load.	Length	% Comp.
0	6.00"	0.00
100	5.86"	2.33
200	5.70"	5.00
300	5.62"	6.33
400	5.475"	8.75
500	5.41"	9.83
750	5.30"	11.68
1000	5.22"	13.00
1250	5.12"	14.65
1500	5.07"	15.50
1750	5.01"	16.50
2000	4.98"	17.00
2250	4.96"	17.31
2500	4.93"	17.81
2750	4.89"	18.50
3000	4.86"	19.00
3500	4.82"	19.67
4000	4.77"	20.50

Correct Compressing Load.

TEST FOR % COMPRESSION 10% MIXTURE. Cont.

Load	Length	% Comp.
5000	4.69"	21.80
5500	4.65"	22.50
6000	4.62"	23.00
6500	4.58"	23.62
7000	4.62"	24.00
8000	4.51"	24.80
9000	4.47"	25.50
10000	4.465"	26.00


TEST FOR —
CORRECT COMPRESSING LOAD
10% MIXTURE
% COMPRESSION
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
PRESSURE
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Test for Compression.

A curve was drawn and is shown on the accompanying page. The percentage of compression is plotted against the load. The curve forms quite a smoothe and regular parabola with the vertex at the origin. At 10,000 pounds pressure it approaches quite close to the horizontal, while at 2000 it approaches quite close to the verticle.

Therefore, no load should be used of less than 2000 pounds in manufacturing processes,as the particles are in a relatively loose condition. By inspecting the curve it becomes apparent that the most desired working pressure would be 3500 pounds. From this point on the small amount of additional compression for increase in load does not warrant its application. The extra costs in machinery and the increased power requirements would also prove a deciding item.

A new test was now run using an 18%

mixture. The results showed very little change. The best pressure ranged between 3250 pounds and 3750 pounds. It might, therefore, be stated that no matter what the proportions of the mixture are, the desired working pressure is 3500 pounds.

Test for Compression

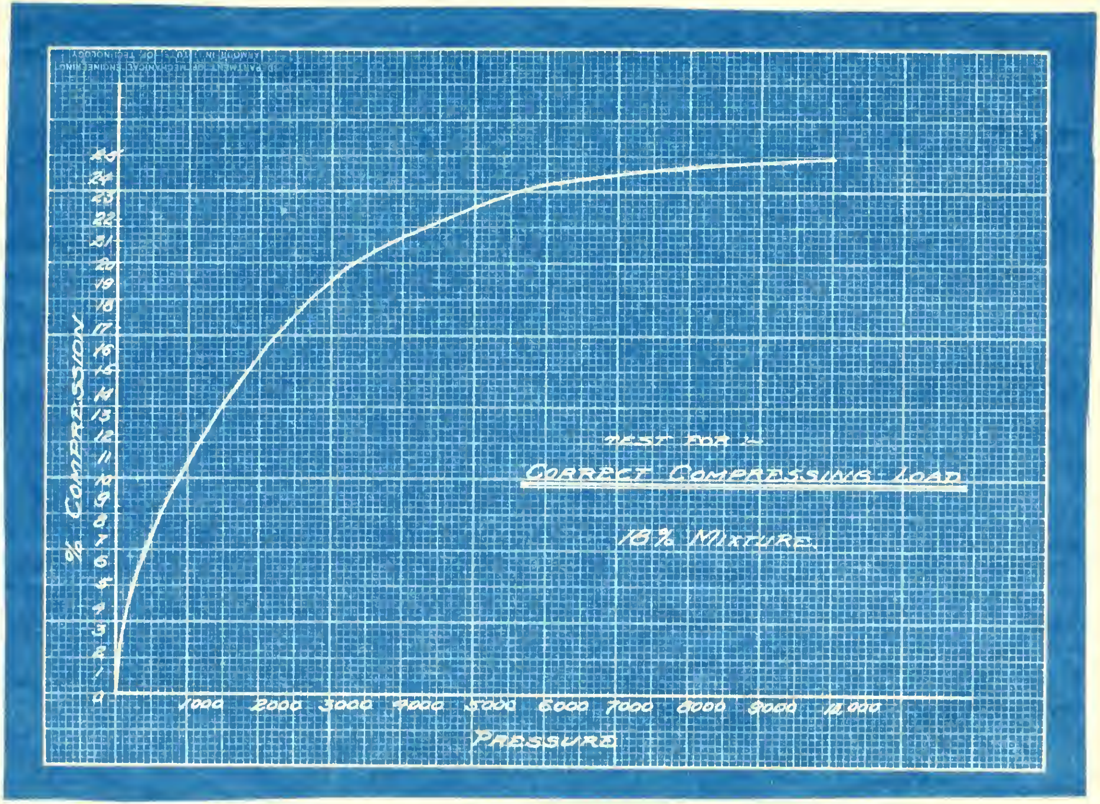
TEST FOR % COMPRESSION 18% MIXTURE.

Load	Length	% Comp.
0	6.25	0.00
100	5.90	5.60
200	5.85	6.40
350	5.80	7.20
500	5.76	7.84
750	5.69	8.96
1000	6.62	10.08
1500	5.42	13.09
2000	5.31	15.01
2500	5.20	16.80
3000	5.64	19.35
3500	4.98	20.32
4000	4.93	21.10
4500	4.89	21.78
5000	4.84	22.58
5500	4.80	23.20
6000	4.77	23.68
7000	4.72	23.68

Test for Compression

TEST FOR % COMPRESSION 18% MIXTURE.

Load	Length	% Comp.
8000	4.71	24.51
9000	4.707	24.70
10000	4.700	24.80


TEST FOR :-
CORRECT COMPRESSING LOAD
18% MIXTURE
% COMPRESSION
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
PRESSURE
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Test For Compression.

THE BEST COMPRESSION LOADING FOR COKED BRIQUETTES

Investigations were now carried on to determine the best compressing load to produce the most economical results after the coking process. It can easily be understood that while the strength of the uncoked briquette might be increased by a certain pressure the same briquette, after it has been coked might display no such characteristics. It was, therefore, the purpose of this test to find the point above this at which the initial compression produced no increase in strength.

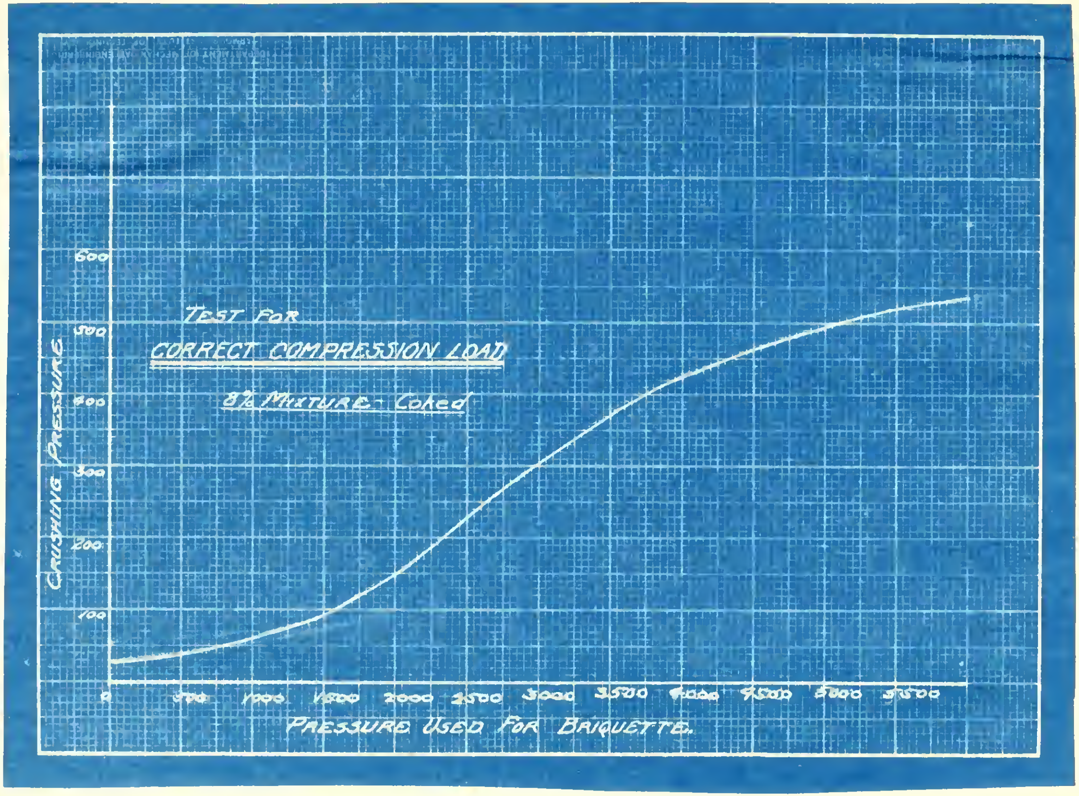
An 8% mixture was made and briquettes were formed varying from an initial pressure of 500 pounds to the final at 1500 pounds. Three were made at eabh increment of 500 pounds. They were coked in the oven and then allowed to set for several days after which they were crushed with the following results:

Test for Compression

Compression Loading For Coked Briquettes

Initial Load	Crushing Strength
500	83
1000	72
1500	90
2000	256
2500	280
3000	391
3500	390
4000	410
4500	421
5000	428

A curve was drawn from which it can easily be seen that the best load for compressing is between 3000 pounds and 4000 pounds. Between these points there is only an increase in the final pressure of 21 pounds, which may be considered as negligable.


TEST FOR
CORRECT COMPRESSION LOAD
8% MIXTURE - Coked
CRUSHING PRESSURE
600
500
400
300
200
100
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
PRESSURE USED FOR BRIQUETTE.

INVESTIGATION FOR CORRECT MIXTURE.

The chief cause for poor briquettes has been on account of improper mixtures and treatment. The only way in which the proper and most desirable composition can be found is to make and investigate every possible mixture.

Mixtures were made varying in composition from 3% to 22%. The coke breeze used was all passed through a No. 10 mesh sieve. It was heated to 240 degrees and then the proper proportion of pitch was added. This was thoroughly mixed and needed, then put in the cylindrical mould. It was then subjected to a load of 3500 pounds. This pressure was used as it was found the most practical in the preceding investigations.

The briquettes formed were then in-

vestigated most carefully and all characteristics made note cf. Several were then crushed and the required load recorded.

Three of each kind are now taken and put in a coke oven. After a thorough heat treatment they are removed, examined and crushed.

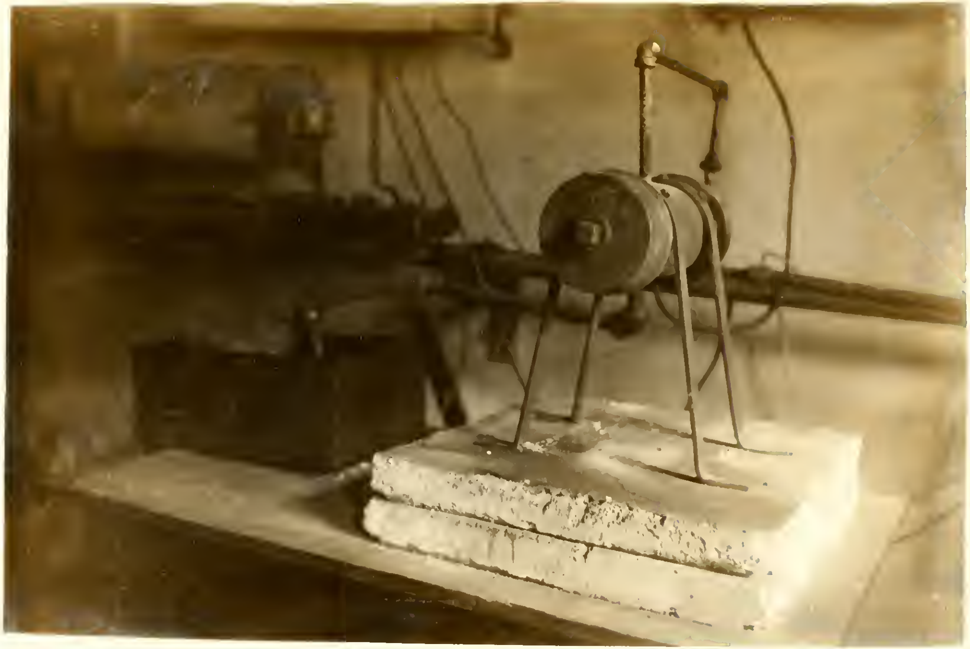
The oven was an especially designed still made exclusively for this test. It consisted of a six inbh diameter cylinder, which was ten inches long. One end was removable so that the briquettes could be inserted and removed easily. The cylinder was set in a brick furnace. The gases were removed through a pipe in the top by means of suction created by a water nozzle. The gases were condensed in the cold water producing the suction. The water and oil flowed into one end of a rectangular pan. The vessel was sections. These consisted of partitions extending a little below the

Investigation For Correct Mixture.

surface of the water. This allowed the water to be drained off, the oil stayed upon the surface and collected. These were easily regulated as the surface of the water rose and fell. The oil was easily skimmed out from between the separators. The furnace was heated by means of a large sized gas burner.

The briquettes were not laid directly upon the bottom of the still but were rested upon a screen shelving. This suspended them and gave an even distribution of heat to all parts.

The following results were obtained:



Coking Oven and Distilling Apparatus without the Surrounding Brick Furnace.

Investigation for Correct Mixture.

3% MIXTURE.

Appearance of briquette before coking:

It was very weak looking and was extremely crumbling and rough at the corners.

Crushing Pressure Before Coking:

Trial	Crushing Pressue.
1	12
2	12
3	8
Average	10.5

Appearance After Coking:

It was in an extremely crumbled condition and fell to pieces when handled roughly.

Investigation For Correct Mixture

Crushing Pressure After Coking:

Trial	Crushing Pressure
1	26
2	11
3	15
Average	17

5% MIXTURE.

Appearance Before Coking:

It was crumbled and fell to pieces when rubbed together hard although great improvement was shown over the three per cent mixture.

Crushing Pressure Before Coking.

Trial	Crushing Pressure.
1	92
2	70
3	110
Average	90

Investigation For Correct Mixture.

Appearance After Coking:

They were much more crumbled than before coking, but could be handled without their going to pieces.

Crushing Strength After Coking:

Trial	Crushing Pressure.
1	206
2	180
3	190
Average	192

Note:

The briquettes crumbled to dust when the structure broke down.

7% MIXTURE.

Appearance Before Coking:

These briquettes assumed a more pleasing appearance than

in any preceding case. The corners were still in a crumbled condition.

Crushing Strength Before Coking:

Trial	Crushing Pressure
1	246
2	282
3	234
Average	253

Appearance After Coking:

They could be handled and still remained their former appearance.

Crushing Strength After Coking:

Trial	Crushing Pressure.
1	206
2	200
3	200
Average	202

Investigation For Correct Mixture.

8% MIXTURE.

Appearance Before Coking:

These briquettes had corners that were more or less sharp. They were not so crumbled and shaggy.

Crushing Strength Before Coking:

Trial	Crushing Pressure.
1	335
2	332
3	327
Average	331

Appearance After Coking:

They were of a light gray color and cracked a little. The corners were only slightly effected, because of the heating. They were too weak to stand hard rubbing.

Investigation For Correct Mixture.

Crushing Strength After Coking:

Trial	Crushing Strength
1	441
2	362
3	401
Average	401

Note:

A new characteristic was displayed in that these briquettes did not crumble into small particles, but sheared.

10% MIXTURE.

Appearance Before Coking:

The corners were nice and sharp but could be broken off by pressing against them hard with the fingers. They could not be broken in two by the bare hands.

Investigation For Correct Mixture.

Crushing Strength Before Coking:

Trial	Crushing Pressure.
1	847
2	1150
3	1100
Average	1033

Appearance After Coking:

The corners were more easily broken but appearance was the same.

Crushing Strength After Coking:

Trial	Crushing Pressure.
1	650
2	656
3	667
Average	658

12% MIXTURE.

Appearance Before Coking:

They were neat and corners were strong.

Investigation For Correct Mixture.

Crushing Strength Before Coking:

Trial	Crushing Pressure.
1	1009
2	986
3	1014
Average	1003

Appearance After Coking:

The briquettes remained neat in appearance but the corners broke easily.

Crushing Strength After Coking:

Trial	Crushing Pressure.
1	850
2	750
3	762
Average	787

Investigation For Correct Mixture.

13% MIXTURE.

Appearance Before Coking:

Neat briquettes with sharp corners. They stood up well and were pleasing in all respects.

Crushing Strength Before Coking:

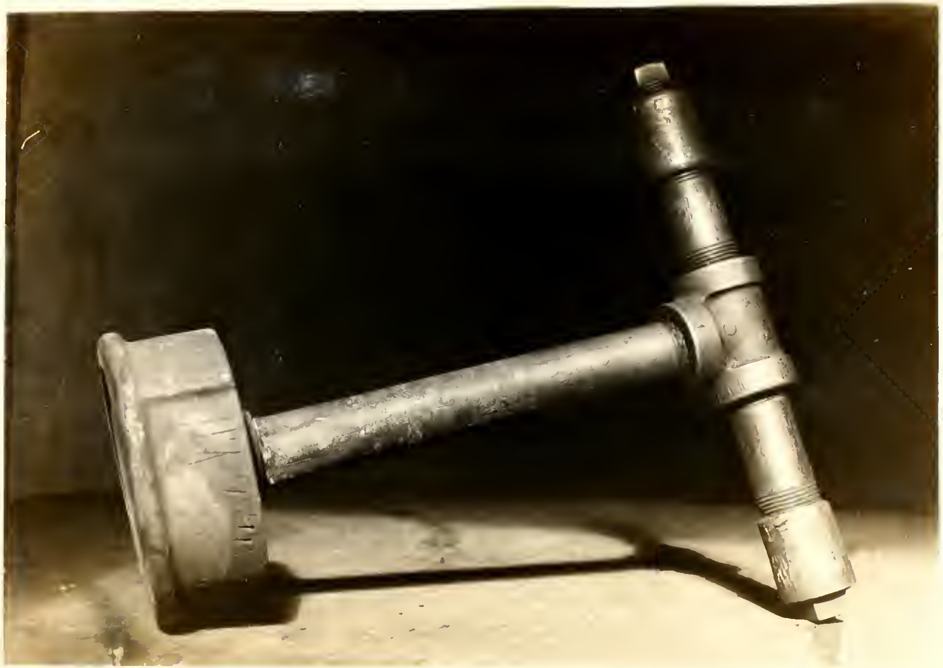
Trial	Crushing Pressure.
1	1200
2	1250
3	1230
Average	1225

Appearance After Coking:

They remained neat but the corners crushed easily.

Crushing Strength After Coking:

Trial	Crushing Pressure.
1	868
2	732
3	746
Average	783



Handle Used In Removing the Cover from the Red Hot Oven.

Investigation For Correct Mixture.

15% Mixture.

Appearance Before Coking:

They were very neat and attractive. A very hard pressure was required to break the corners.

Crushing Strength Before Coking:

Trial	Crushing Pressure.
1	1000
2	1300
3	1550
Average	1287

Appearance After Coking:

They remained neat but the corners could be broken off when pressed hard.

Crushing Strength After Coking:

Trial	Crushing Strength.
1	1010
2	870
3	806
Average	895

Investigation For Correct Mixture.

16% MIXTURE.

Appearance Before Coking:

The briquettes were very clean looking and regular. The sides were very smooth and the corners sharp.

Crushing Strength Before Coking:

Trial	Crushing Strength.
1	1220
2	1304
3	1240
Average	1255

Appearance After Coking:

They looked strong and compact. They could be handled roughly and would not break apart but still the corners would crumble too much for a commercial article.

Investigation For Correct Mixture.

Crushing Strength After Coking:

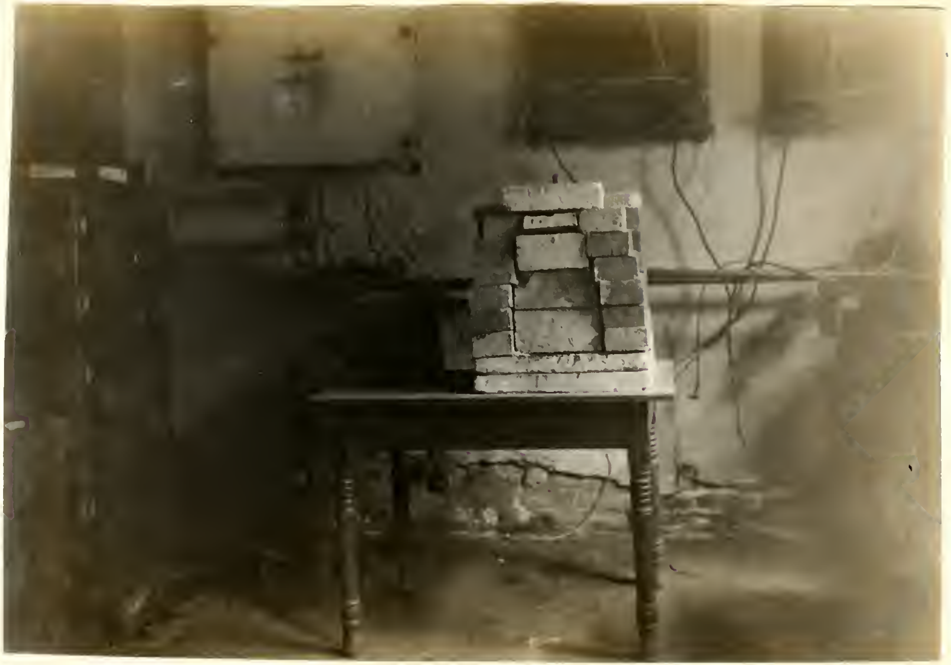
Trial		Crushing Pressure.
1	- - - - - - - -	920
2	- - - - - - - -	1004
3	- - - - - - - -	940
	Average	955

18% MIXTURE.

Appearance Before Coking:

The Briquettes were very neat and regular. The sides were shiny and smooth. The corners could not be crushed off. The mixture used in its composition was very soft and plastic. Taking all things into account, they were ideal briquettes.

Crushing Strength Before Coking:



Coke Oven and Still in full Operation.

Investigation For Correct Mixture.

Trial	Crushing Pressure.
1	2200
2	2200
3	2320
Average	2240

Appearance After Coking:

They retained their rigid and smooth appearance. They lost the shiny black tar hue and took on the characteristic grey color of coke. The corners were good and strong and could not be broken.

Strength After Coking:

Trial	Crushing Strength
1	1100
2	1250
3	1150
Average	1167

Investigation For Correct Mixture.

20% MIXTURE.

Appearance Before Coking:

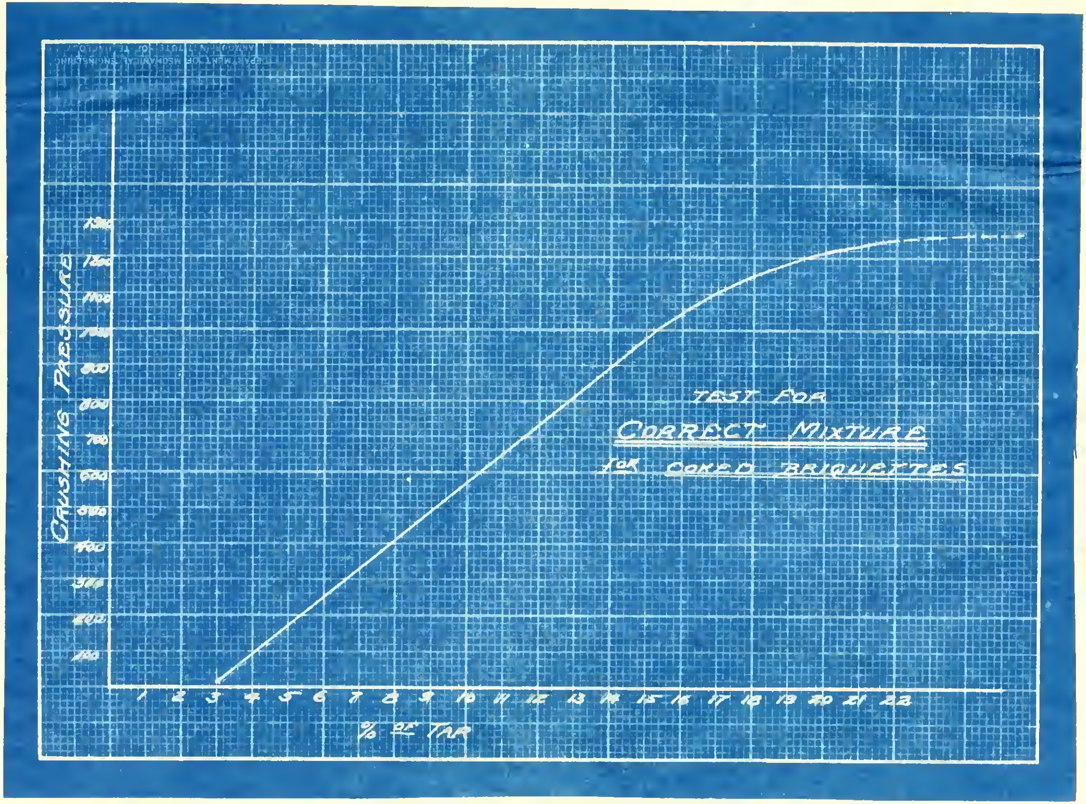
They were smooth and glossy. The mixture forming its composition showed a slight tendency to stick to the mould. The corners were sharp and they were excellent to look at.

Crushing Strength Before Coking:

Trial	Crushing Pressure.
1	2930
2	2936
3	2950
Average	2935

Appearance After Coking:

They retained their sharp corners, but the cylindrical shape was slightly distorted to an elliptical cross-section. This showed that the tar between the particles flowed a little before it was evaporated off.


TEST FOR
CORRECT MIXTURE
FOR COKED BRIQUETTES
CRUSHING PRESSURE
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
% OF TAR
DEPARTMENT OF MECHANICAL ENGINEERING
ARMOUR INSTITUTE OF TECHNOLOGY

Investigation For Correct Mixture.

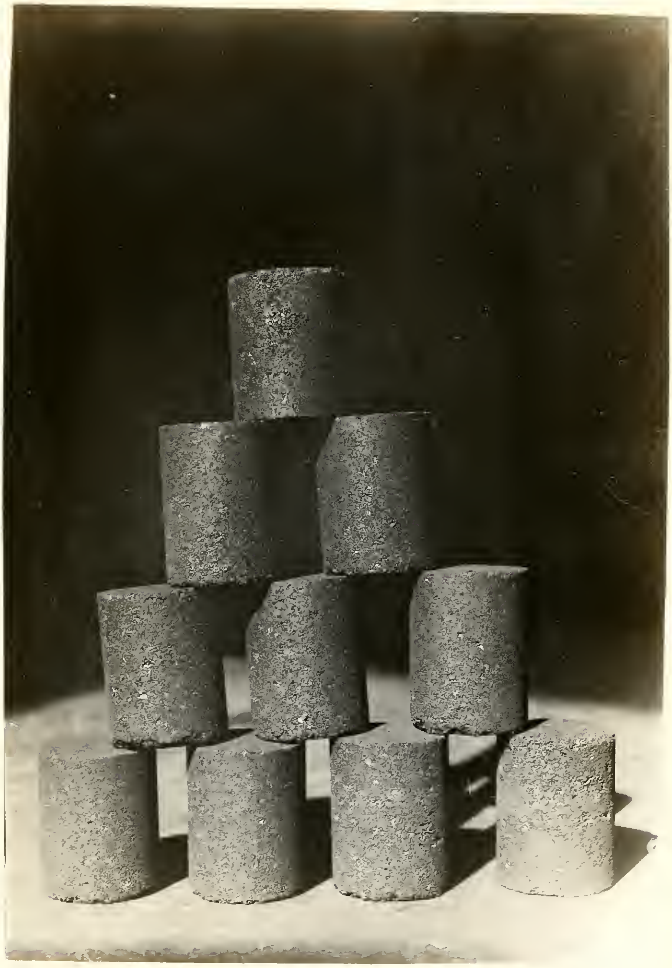
Crushing Strength After Coking:

Trial	Crushing Pressure.
1	1000
2	1200
3	1150
Average	1150

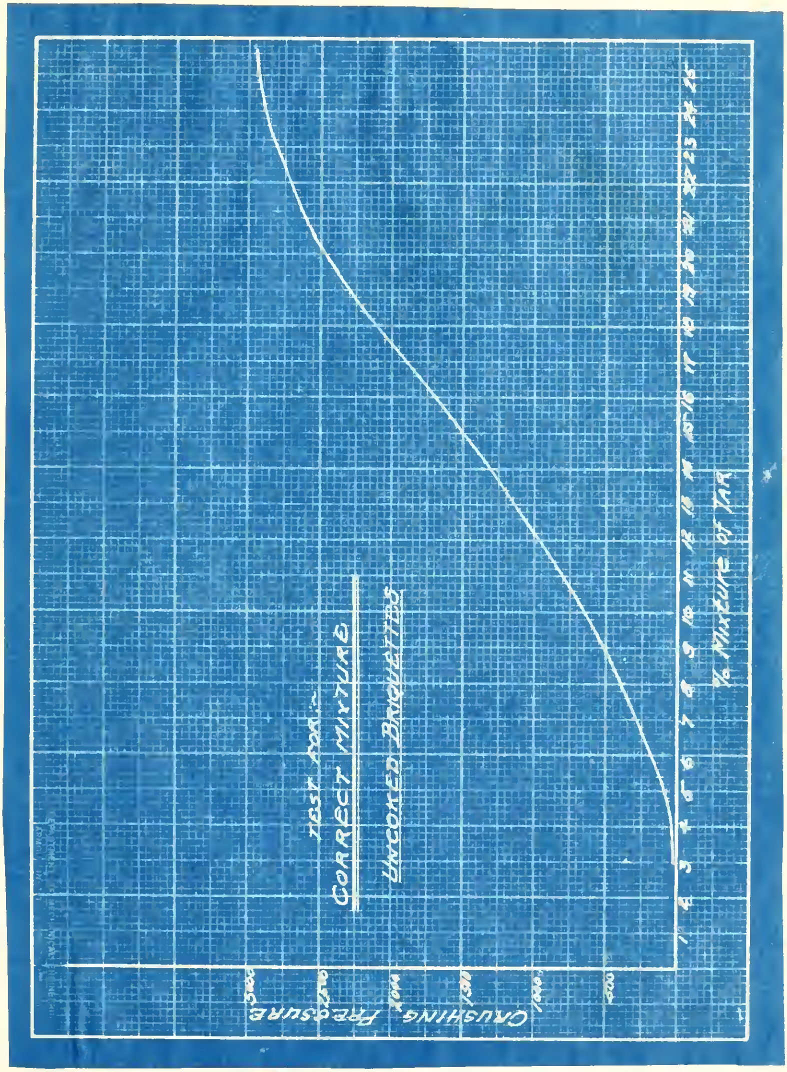
22% MIXTURE.

Appearance Before Coking:

The briquettes were smooth and shiny showing little difference than the 20% mixture. The composition was very sticky when briquetted and caused considerable trouble. It adhered to everything with whihh it came in contact. There was clearly an excess of the tar so no higher percentage mixtures were made.



Coke Breeze Briquettes Before Coking.


TEST FOR:-
CORRECT MIXTURE
UNCOKED BRIQUETTES
CRUSHING PRESSURE
500
1000
1500
2000
2500
3000
% MIXTURE OF TAR
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25

Investigation For Correct Mixture.

Crushing Strength After Coking.

Trial	Crushing Strength.
1	1210
2	1196
3	1230
Average	1212

The results of the test are plotted on cross-section paper. The crushing pressure is plotted against the corresponding percentage of mixture. The coked and uncoked are drawn separately.

The curve drawn for the briquettes in their natural condition shows a constant increase in their strength up to 25% from which point on they vary little. The coked ones show a constant increase only up to 16%. From this to 20% the curve rounds gradually to the horizontal with practically no further rise.

Investigation For Correct Mixture.

It can therefore be said that in order to obtain the best and most desirable briquettes an 18% mixture should be used.

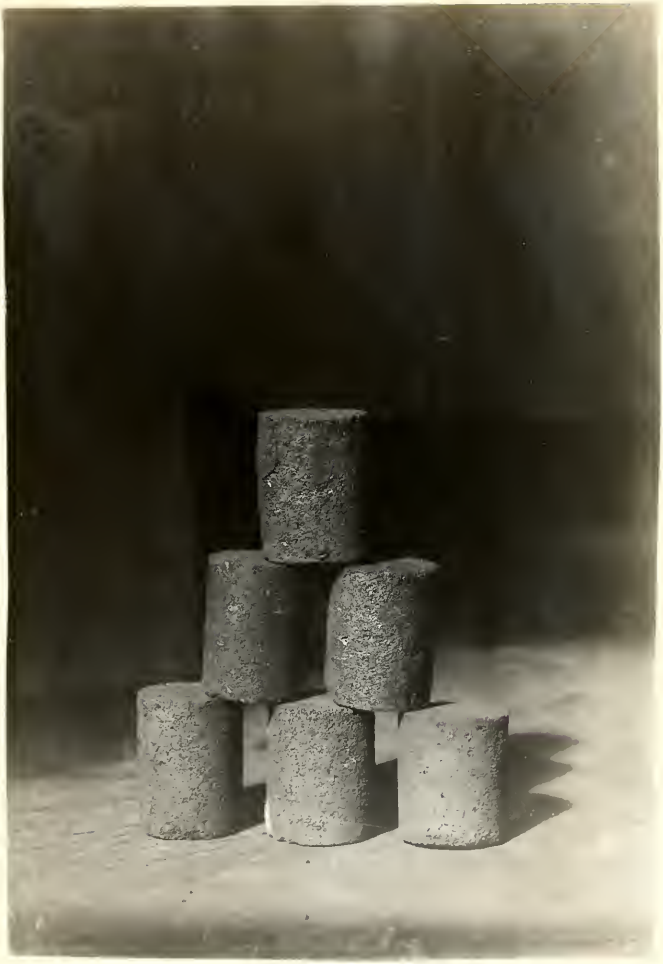
Tabulated the reasons are:

I. The briquettes have the greatest strength in relative proportion to their mixture.

II. They have a fine appearance and do not crumble and chip.

III. When broken down in structure the particles are rigid pieces which still retain the firing qualities.

IV. The mixture used in their composition is easy to handle, is plastic, and does not stick to the mould.



Coke Breeze Briquettes After Coking.

COMBUSTIBILITY.

One hundred pounds of the briquettes were manufactured. They were made from an 18% mixture, and under the standard compression load of 3500 pounds. They were then coked in the oven.

The ooked briquettes were then burnt in a common house hot air furnace. They were kindled with wood and treated in no respetts different than were then anthracite coal. The briquettes ignited quite easily.

They burnt uniformly on the grate, the fire atall stages of combustion being uniform throughout. When the draft was full open they glowed brightly emitting a blue flame whose length never exceeded two inches. The heat given off was intense. When the draft was shut off they glowed with red color. They were subjected to a small draft for eight hours after which time the fire was

still burning. The draft was then increased a little and they continued to burn until only a few small isolated particles were left.

The burning of these briquettes was remarkable because of the high efficiency shown. As they burned the small particles of whihh they were composed on the outside turned to a red ash and fell off. This left the fresh particles underneath exposed. These would burn, and they in turn fall off. This process continued until the whole was consumed. As a result practically all of the heating value of the fuel is made available. The resulting ash was a very fine and red powder, whihh was as uniform throughout as if it were sifted.

Coke Breeze Briquettes are, therefore, an ideal fuel for domestic purposes when manufactured in the prescribed manner and

Combustibility.

should easily supplant and prove far more preferable to any hard coal upon the market.

APPENDIX

BIBLIOGRAPHY.

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Nov. 23, 1912. Page 18.

"Iron Trade Review"

Aug. 9, 1917. Page 281.